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EP 0 607 884 A1

(54) **Optical waveguide and method of fabricating the same.**

(57) An optical waveguide comprising a core of quartz as a main component, and a cladding layers surrounding the core is formed by deposition of glass fine particles by flame hydrolysis. This method includes a step of transiently increasing a feed amount of phosphorus to a flame burner in forming the cladding layers. The method for fabricating an optical waveguide according to this invention is for fabricating a core (132a) or cladding layers (122,142) surrounding the core (132a) by flame hydrolysis deposition and is characterized in that the glass fine particle layers are vitrified after the deposition of the phosphorus-content glass fine particle layer, whereby glass films (122a,122b) with a thickness of below 10 μm are formed. This glass film forming step is repeated twice or more times to form the core or the glass layers to be the cladding layers surrounding the core. This invention can suppress inhomogeneous vitrified films and especially can make phosphorus concentrations in the cladding layers uniform. As a result, propagation losses can be made small.

Fig. 16C
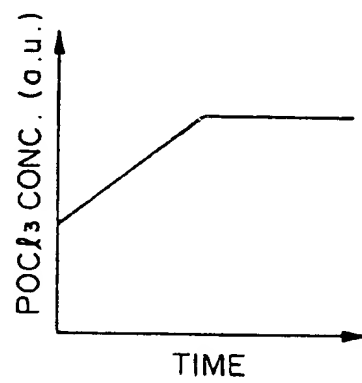
BACKGROUND OF THE INVENTION

Field of the Invention

5   This invention relates to an optical waveguide fabricated by flame hydrolysis deposition, and a method for fabricating the same. Specifically this invention relates to a method for forming a core or a cladding layer of phosphorus content glass film.

Related Background Art

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Optical waveguides are expected to be one of prospective basic devices of optical systems. Various types of optical waveguides have been proposed, and one of them comprises a core formed mainly of quartz, and a cladding surrounding the core, whereby signal beams are confined in the core to be propagated therethrough. The optical waveguide of this type has the doped core, and the cladding by flame

15   hydrolysis deposition. For example, a known flame hydrolysis deposition (Japanese Patent Laid-Open Publication No. 105111/1983) comprises depositing glass fine particles are deposited from a flame burner to form a porous glass fine particle layer, and heating and vitrifying the glass fine particle layer.

SUMMARY OF THE INVENTION

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But propagation losses of the optical waveguides formed by this conventional flame hydrolysis deposition are not sufficiently low. The inventors of the present application have found that their high propagation losses are due to inhomogeneous phosphorus concentrations in the core or the cladding.

An object of this invention is to provide an optical waveguide having a cladding or a core having a

25   homogeneous phosphorus concentration distribution, and a method for fabricating the same.

A first method for fabricating the optical waveguide according to this invention relates to a method for fabricating an optical waveguide which comprises

a lower cladding layer of quartz as a main component formed on a substrate, a core of a quartz as a main component formed on the lower cladding layer, and an upper cladding layer of a quartz as a main

30   component formed on the lower cladding layer with the core buried in, a process for forming the lower cladding layer being a flame hydrolysis deposition step of supplying phosphorus-content gas and silicon-content gas to a burner, blowing glass fine particles of phosphorus-content quartz as a main component from the burner to deposit the same on the substrate and form the lower glass fine particle layer, the flame hydrolysis deposition step comprising: a step including a period of time in which a flow rate of the

35   phosphorus-content gas is increased with respect to a flow rate of the silicon-content gas, and a step of heating and vitrifying the lower glass fine particle layer.

In this lower cladding layer flame hydrolysis depositing step
a flow rate of the phosphorus-content gas may be transiently increased step functionally or linearly. In this depositing step a minimum value of the flow rate of the phosphorus-content gas is 0.

40   A second method for forming the lower cladding layer having high uniform phosphorus concentrations may comprise the following steps; i.e., the lower cladding layer may be formed by repeating by plural times a step of supplying phosphorus-content gas and silicon-content gas to a burner, blowing glass fine particles of phosphorus-content quartz as a main component from the burner to form a glass fine particle layer; and a step of heating and vitrifying the glass fine particle layer.

45   In the lower cladding layer flame hydrolysis depositing steps of the first and the second methods, the silicon-content gas can be $SiCl_4$, and the phosphorus-content gas can be selected from one of $POCl_3$, PCl_4, and the mixture thereof.

In the first and the second fabrication methods, the core can be formed by following a flame hydrolysis deposition step of supplying the phosphorus-content gas and the silicon-content gas to the burner, blowing

50   glass fine particles of the phosphorus-content quartz as a main component to the lower cladding layer from the burner and form a core glass fine particle layer, a vitrifying step of heating and vitrifying the core glass fine particles to form a core layer, and a lithography step of etching the core layer by lithography to expose the lower cladding layer.

This core can be formed also by following, after the flame hydrolysis deposition step for forming the

55   lower glass fine particle layer in the first fabrication method, the flame hydrolysis deposition step of supplying the phosphorus-content gas and the silicon-content gas to the burner, blowing the glass fine particles of phosphorus-content quartz as a main component from the burner to deposit the same on the lower glass fine particle layer, the vitrifying step of heating and vitrifying the lower glass fine particle layer

and the core glass fine particle layer to form a core layer, and a lithography step of etching the core layer by lithography to expose the lower cladding layer.

In the first and the second fabrication methods, the core can be formed by the flame hydrolysis deposition step and the vitrifying step as the lower cladding layer can be formed. In the upper cladding layer flame hydrolysis deposition step as well, the silicon-content gas is SiCl4, and the phosphorus-content gas is selected from one of POCl3, PCl4 and the mixture thereof, in the flame hydrolysis deposition step for forming the upper cladding layer.

By these methods, an optical waveguide having at least one of the lower cladding layer and the upper cladding layer being doped with phosphorus, and having the phosphorus-doped layer whose thickness-wise phosphorus concentrations have uniformity which is indicated by a minimum value above 75 when a maximum value of the thickness-wise phosphorus concentrations is indicated by 100.

In the first method for fabricating an optical waveguide, which includes the step of transiently increasing a feed amount of phosphorus-content gas supplied to the flame burner in depositing the glass fine particle layers to be the cladding layers, phosphorus concentrations in the finished vitrified optical waveguide films can be substantially uniform. Although it is not empirically certified, it is assumed that phosphorus from the flame burner is added not only to the glass fine particle layers being deposited, but also to already deposited glass fine particle layers. Accordingly it is considered that more phosphorus is distributed lower parts of the glass fine particle layers. In forming the glass fine particle layers, phosphorus is added in a smaller amount for the deposition at lower parts of the glass fine particle layers, and then the amount is increased for the deposition, whereby it is considered that the phosphorus can be distributed homogeneously in the glass fine particle layers. Accordingly concentrations of the phosphorus in the finished vitrified optical waveguide film can be uniform.

When low phosphorus concentrations are necessary in the films, the glass fine particles are deposited without feeding phosphorus to the flame burner, whereby a general concentration of the phosphorus can be low.

In the method for fabricating an optical waveguide according to this invention, the glass layers to be the core or the cladding layers are formed of glass films containing phosphorus. The phosphorus is distributed more in lower parts of the glass film. But changes of the phosphorus distribution can be made small by forming the glass films in a thickness of below 10 μm. By forming such glass films, the core or the cladding layers having small phosphorus distribution changes can be formed in a required thickness.

The thus-fabricated optical waveguide according to this invention is free from locally deviated phosphorus deposition.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A, 1B, 1C, 1D, and 1E are sectional views of the optical waveguide in the respective fabrication steps.

Fig. 2 is a graph of feed amounts of the raw material gases for the formation of the lower cladding layer in a first embodiment.

Fig. 3 is a graph of feed amounts of the raw material gases for the formation of the core layer in the first embodiment.

Fig. 4 is a graph of the compositions of the glass films formed by the method according to the first embodiment.

Fig. 5 is a graph of the feed amounts of the raw material gases for the formation of the upper cladding in the first embodiment.

Fig. 6 is a graph of the compositions of the glass films of the optical waveguide fabricated by the first embodiment.

Fig. 7 is a graph of the feed amounts of the raw material gases in a second embodiment.

Fig. 8 is a graph of the compositions of the glass films of the optical waveguide fabricated by the second embodiment.

Fig. 9 is a graph of the feed amounts of the raw materials of controls for the second embodiment.

Fig. 10 is a graph of the compositions of the glass films of the optical waveguide fabricated by the above control.

Figs. 11A, 11B, 11C, and 11D are sectional views of the optical waveguide in the respective fabrication steps.

Fig. 12A, 12B, 12C, and 12D are sectional views of the optical waveguide in the respective fabrication steps.

Fig. 13 is a graph of the compositions of the glass films prepared by the method according to a third embodiment.

Fig. 14 is a graph of the compositions of the glass films prepared by the method according to the fourth embodiment.

Fig. 15 is a graph of the compositions of the glass films prepared by controls.

Figs. 16A, 16B, 16C, and 16D are graphs of patterns of changes of feeding flow rates of POCl4.

Fig. 17A is a perspective view of the internal structure of the fabrication device, Fig. 17B being a perspective view showing details thereof.

Fig. 18 is a view explaining a feed system of POCl4 gas.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first embodiment of this invention will be specifically explained. In the first embodiment, a cladding layer and a core layer by the following flame hydrolysis deposition using the apparatus of Fig. 17A.

Each Si substrate 110 for glass fine particles to be deposited on is a 3 inch (75mm)-diameter Si wafer, and Si substrates are mounted on a turntable 16 in a reaction vessel 300. The reaction vessel 300 is a rectangular prallelopiped vessel of a 740 mm-width, 760 mm-thickness and 200 mm-height. A pressure in the reaction vessel 300 is reduced by a (vacuum pump) scrubber (displacement: -0.1 to -0.3 mmH2O).

The turntable 16 has a 600 mm diameter and has a heater 301 buried in (as shown in Fig. 17B). A thermocouple 302 of Chromel-Alumel is in contact with the turntable 16, so that temperatures of the Si substrates 110 heated by the heater 301 can be indirectly monitored.

Thus temperatures of the surfaces of the Si substrates 110 for glass fine particles 14 to be deposited on can be maintained at about 600°C by the thermocouple 302. Glass fine particles from a flame burner 12 are deposited on the Si substrates 110. Concurrently therewith the turntable 16 is turned at 10 rpm, and the flame burner 12 is reciprocated diametrically in the direction of turn thereof over 200 mm at an average speed of 6 mm/min. Thus, the glass fine particles 14 from the flame burner 12 can be uniformly deposited on the Si substrates 110. An exhaust pipe 20 is to be located near the respective Si substrate 110 to discharge surplus glass fine particles 14. Temperatures of the surface of the Si substrate 110 at the time of the deposition of the glass fine particles were measured by a radiation thermometer 303. This optical pyrometer 303 was IT-1650 made by KEYENCE Kabushikikaisha. Temperatures of the surfaces of the Si substrates 110 being heated by the flame burner 12 during the deposition of the glass fine particles 14, which were measured by the radiation thermometer were about 550°C. That is, when an indirect measurement temperature of the Si substrates 110 given by the thermocouple 302 is 600°C, temperatures of the Si substrates 110 measured by the optical pyrometer 303 are 550°C. A heat insulating material is provided on the inside wall of the reaction vessel 300 so that a uniform temperature is given in the reaction vessel 300.

Then, the glass fine particles 14 deposited on the Si substrates 110 together with the Si substrates 110 are heated at high temperatures to be vitrified, and glass films are formed.

The Si substrates were cleaned by a chemical surface treatment and thermal cleaning. That is, the Si substrates 110 were subjected to the chemical surface treatment with hydrofluoric acid, and then loaded for the thermal cleaning in the reaction vessel 300 to be heated up to 600°C (measured by the thermocouple 302) by resistance heating of the turntable 16 while the flame burner 12 being fed with hydrogen gas and oxygen gas at a set ratio is traversed over the surfaces of the Si substrate 110. The temperature was measured by the thermocouple. A temperature increase rate up to 600°C was 5°C/min. Using this apparatus, a lower fine particle layer

120 (glass fine particle layer) for a lower cladding layer of SiO_2-P_2O_5-B_2O_3 is deposited on each Si substrate 110, and then a core fine particle layer 130 (glass fine particle layer) for a core layer of SiO_2-GeO_2-P_2O_5-B_2O_3 (Fig. 1A). Feed amounts of the raw materials fed to the flame burner 12 were as follows. A time schedule of the gases used in the formation of the lower fine particle layer 120 for the cladding layer is shown in Fig. 2, and that of the gasses used in the formation of the core fine particle layer 130 for the core layer is shown in Fig. 3.

A temperature measured by the optical pyrometer 303 at the time of the deposition was 550°C.

1) Lower fine particle layer for the lower cladding layer

(45 minutes)
_____

SiCl$_4$: 100   cc/min

POCl$_3$:   3.0 cc/min (for 15 mins. after the start of

the deposition)

POCl$_3$:   5.0 cc/min (for 30 mins. after the end of

the deposition)

BCl$_3$: 15   cc/min

Ar   :   2   l/min

H$_2$:   2   l/min

O$_2$:   6   l/min

2) Core fine particle layer for the core layer

(15 minutes)
_____

SiCl$_4$: 100   cc/min

GeCl$_4$: 10   cc/min

POCl$_3$:   5.0 cc/min

BCl$_3$: 15   cc/min

Ar   :   2   l/min

H$_2$:   2   l/min

O$_2$:   6   l/min

The flow rates of the fed gases were measured by the flow rate controller made by NIPPON TYLAN Kabushikikaisha. The flame burner 12 comprises four conically arranged cylinders as shown in Fig. 17B. Innermost cylinders of the flame burner 12 are fed with reaction gases, such as POCl$_3$ gas, SiCl$_4$, GeCl$_4$, BCl$_3$, etc. Hydrogen gas is fed inbetween the innermost cylinders and the second innermost cylinders. Two l/min of Ar gas stated above is fed inbetween the second innermost cylinders and the third innermost cylinders. Oxygen gas is fed inbetween the third innermost cylinders and the fourth innermost cylinders. Ar gas is caused to thus flow between the hydrogen gas and the oxygen gas, whereby reaction between the hydrogen gas and the oxygen gas at the end of the gas emitting orifice of the gas burner 12 can be suppressed.

The POCl$_3$ gas above stated is fed into the reaction vessel 300 by the apparatus of Fig. 18 on a carrier of Ar gas different from the two l/min of Ar gas for the suppression of the reaction of the hydrogen gas and the oxygen gas. In this apparatus, first, Ar gas is introduced into the POCl$_3$ in a tank 181 through a pipe 184 at a flow rate controlled by a flow rate controller 180. Then the Ar gas is bubbled in the liquid POCl$_3$, and the Ar gas containing the POCl$_3$ gas is introduced into the pipe 182. The pipe 182 is in communication with the reaction vessel 300 so that the Ar gas and the POCl$_3$ gas are fed into the flame burner 12 in the reaction vessel. The pipe 182 is partially in a condenser 183 for cooling the pipe 182, so that the gas

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flowing through the pipe 182 is kept at a set temperature.

A flow rate of the $POCl_3$ gas was 5 cc/min at a certain period of time. During the certain period of time, a temperature of the tank 181 was 25°C, a temperature of the condenser 183 being 20°C, a vapor pressure of the $POCl_3$ being 30 mmHg, and a flow rate of the Ar as a carrier gas being 121.7 cc/min which

5 corresponds to 5 cc/min of the $POCl_3$ gas. The Ar gas, which is inert, does not react with the $POCl_3$ gas and is effective as a carrier gas for the $POCl_3$ gas. As a carrier gas for the $POCl_3$ gas, other rare gas, such as He, Ne, Kr, Xe, etc., are usable.

In this embodiment, $POCl_3$ is used to dope phosphorus, but PCl_4 may be used in place of $POCl_3$.

The double structure of the glass fine particle layers 120, 130 of Fig. 1A thus deposited is vitrified by

10 heating up to 1380°C in an atmosphere of $He:O_2 = 10:1$, and a transparent glass film comprising a lower cladding layer 122 and a core layer 132 was prepared (Fig. 1B). A heating temperature for the vitrification was measured by a thermocouple of platinum of platinum rhondium (13%) disposed in the electric furnace not shown.

A concentration distribution of phosphorus pentoxide (P_2O_5) thickness-wise of the thus prepared glass

15 film was analyzed by an EPMA (Electron Probe X-ray Microanalyzer) not shown. The EPMA measuring apparatus used in this embodiment was GXA-8621M made by Nippon Denshi Kabushikikaisha (JEOL, LTD). In measuring its concentrations, the lower cladding layer 122 and the core layer 132 were polished using diamond abrasive materials to expose their thickness-wise sectional surfaces. In the polishing, 9 μm, 3 μm and 1 μm particle size-diamond abrasive materials were used in the stated order to expose sectional

20 surfaces as flat and smooth as possible. The thus-prepared samples were loaded in the EPMA measuring apparatus, and phosphorus concentrations were measured at a 7 kV acceleration voltage and a 2×10^{-7} A current.

The thus-formed lower cladding layer 122 and the core layer 132 respectively had a 10±0.6 μm thickness and a 30±1.5 μm thickness. The thickness was measured by a Scanning Electron Microscope

25 made by NIPPON DENSHI Kabushikikaisha (JEOL). The measured phosphorus concentration distribution is shown in Fig. 4.

The solid line in Fig. 4 indicates a concentration profile (wt%) of phosphorus pentoxide (P_2O_5) in the a-a' section in Fig. 1B. As shown in Fig. 4, P_2O_5 concentrations are in a range of 1.2 - 1.4 wt% in the lower cladding layer 122. It is seen that a glass film having a homogeneous thickness-wise distribution of

30 phosphorus concentrations. Concentrations of B_2O_3 were substantially uniformly 1.8 wt% in the lower cladding layer 122. The core layer 132 contains Ge, and has higher refractive indexes than the lower cladding layer 122 and an upper cladding layer 142 which will be formed later.

Grounds for increases of a phosphorus feed amount in thus forming the glass fine particle layers can make phosphorus concentrations in the lower cladding layer uniform are considered to be as follows.

35 Phosphorus in the flame burner 12 is added to the formed glass fine particle layers. Accordingly a phosphorus added amount in the glass fine particle layers is a total of an added amount during the deposition, and an added amount after the deposition. Although it depends on thicknesses of the glass fine particle layers, the effect of changes in a phosphorus feed amount supplied to the flame burner 12 is generally considered larger during the deposition of the glass fine particle layers than after their deposition.

40 Thus, by suitably adjusting an increase in a feed amount of phosphorus to the flame burner 12 during the deposition as described above, phosphorus concentrations in the glass fine particle layers or an optical waveguide prepared by vitrifying the glass fine particle layers can be kept substantially uniform. In addition, it is considered that the heating for vitrification following the formation of the lower glass fine particle layer 120 sufficiently diffuses phosphorus, with the result that phosphorus concentrations in the lower cladding

45 layer 122 can be more uniform.

The one-dot line and the dot line in Fig. 4 indicate the results of controls for making sure the above-described effect. The one-dot line in Fig. 4 indicates the composition analysis result of the vitrified glass film in the case that a feed amount of $POCl_3$ was kept always at 5.0 cc/min in the formation of the lower fine particle layer 120 (the other conditions were the same as in the steps of Figs. 1A and 1B). P_2O_5

50 concentrations in the lower cladding layer 122 was 2.2 wt% near the substrate, and 1.4 wt% at a 20 μm-thicknesswise position in the lower cladding layer 122 (with the boundary between the substrate and the lower cladding layer set at the origin), and it was found that the phosphorus concentration distribution largely deviates thicknesswise.

The dot line in Fig. 4 indicates the composition analysis result of the vitrified glass film in the case that

55 a feed amount of $POCl_3$ was kept always at 3.0 cc/min in the formation of the lower fine particle layer 120 (the other conditions were the same as in the steps of Figs. 1A and 1B). P_2O_5 concentrations in the lower cladding layer 122 was 1.3 wt% near the substrate, and 0.8 wt% at a 20 μm-thicknesswise position in the lower cladding layer 122. The phosphorus concentration distribution largely deviates as indicated by the

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one-dot line.

Thus, in the method for fabricating the optical waveguide according to this embodiment, an optical waveguide having thickness-wise concentrations of phosphorus in the phosphorus-doped lower cladding layer 122 or upper cladding layer 142 whose minimum thickness-wise concentration is at least above 75 with a maximum thickness-wise concentration set at 100 could be fabricated. In this embodiment, the minimum value is above 95.

Then, a region of the glass film for the core layer 132 to be formed in Fig. 1B was formed into 10 μm-width straight ridges by photolithography and reactive ion etching (RIE), and a core 132a was formed (Fig. 1C). The thus-formed core 132a had a 8 μm-width and a 8 μm-thickness. The reaction gases used in the RIE were C_3H_8 and CCl_4. Then, on the core 132a and the lower cladding layer 122, a glass fine particle layer 140 of $SiO_2-P_2O_5-B_2O_3$ for the upper cladding layer was deposited for 45 minutes (Fig. 1D). The conditions for this deposition were a little different from those for the deposition of the lower cladding layer 122, and feed amounts of the raw materials supplied to the flame burner 12 were as follows. Fig. 5 shows the time schedule of the gases used in the formation of the glass fine particle layer 140.

1) Upper fine particle layer for the upper cladding layer

$SiCl_4$	100 cc/min
$POCl_3$	10.0 cc/min (for 15 minutes after the start of the deposition)
$POCl_3$	15.0 cc/min (for 30 minutes after the end of the deposition)
BCl_3	50 cc/min
Ar	2 l/min
H_2	2 l/min
O_2	6 l/min

A rotation number of the turntable 16, a diameter of the turntable, conditions for traversing the flame burner 12, etc. were the same as in the step shown in Fig. 1A. A flow rate of the $POCl_3$ gas was 10 cc/min at a certain period of time. During the certain period of time, a temperature of the tank 181 was 40°C, a temperature of the condenser 183 being 35°C, a vapor pressure of the $POCl_3$ being 60 mmHg, and a flow rate of the Ar as a carrier gas being 116.7 cc/min which corresponds to 10 cc/min of the $POCl_3$ gas.

The glass fine particle layer 140 thus formed on the glass film comprising the core 132a and the lower cladding layer 122 was heated up to 1250°C in an atmosphere of $He:O_2$ = 10:1 for vitrification, and an optical waveguide including the core 132a between the lower cladding layer 122 and the upper cladding layer 142 was prepared. Fig. 1E shows the sectional structure of the optical waveguide. As shown in Fig. 1E, the lower cladding layer 122 is formed on the Si substrate 110, and the core 132a in the form of straight ridges is formed. The upper cladding layer 142 is further formed in such a manner as to cover the core 132a. An element distribution in the A-A' section of the optical waveguide of Fig. 1E was measured in the same way by the EPMA.

In Fig. 6 the solid line indicates a profile of phosphorus pentoxide (P_2O_5) concentrations in the A-A' section. It is found that P_2O_5 concentrations in the upper cladding layer 142 were in a range of 3.7 - 4.0 wt% and are substantially uniform thicknesswise. The P_2O_5 concentration is decreased in the uppermost part (65 - 70 μm-thicknesswise position in the glass film) of the upper cladding layer 142, which is considered to cause no substantial influence on optical waveguiding conditions in the core 132a.

The one-dot line and the dot line in Fig. 6 indicate the results of controls for making sure the above-described effect. The one-dot line in Fig. 6 indicates the result of the composition analysis of the glass film after the vitrification in the case that a feed amount of $POCl_3$ was kept always at 15 cc/min in the formation of the glass fine particle layer (the other conditions were the same as in the steps of Figs. 1D and 1E). P_2O_5 concentrations in the upper cladding layer 142 deviated in a range of 5.9 to 4.0 wt%, and it is found that phosphorus depth-wise concentrations cannot be made uniform.

The dot line in Fig. 6 indicates the result of the composition analysis of the glass film after the vetrification in the case that a feed amount of $POCl_3$ was kept 10cc/min. in the formation of the glass fine particle layer (the other conditions were the same as in the steps of Figs. 1D and 1E). P_2O_5 concentrations in the upper cladding layer 142 deviated in a range of 4.0 - 2.6 wt%, and it is found that phosphorus depth-wise concentrations cannot be made uniform.

As evident from the results of Figs. 4 and 6, in the method for fabricating the optical waveguide according to this invention, even with some changes to the conditions, the cladding layers 122, 142 can have substantially uniform phosphorus compositions. That is, suitable adjustment of increases of a feed

amount of phosphorus supplied to the flame burner 12 can keep phosphorus concentrations contained in the vitrified optical waveguide substantially uniform. Accordingly refractive index distributions of the cladding and the core can be made substantially uniform, and the thus fabricate optical waveguide can have small propagation losses.

5   A second embodiment of this invention will be explained. The method for fabricating the optical waveguide according to this embodiment is for securing uniform phosphorus width-wise concentrations in the glass film.

This embodiment is the same as the first embodiment but is different from the latter in that in the step of Fig. 1D the conditions for forming the glass fine particle layer 140 on the glass film (the lower cladding 10   layer 122 and the core 132a), and the conditions of the later heat treatment are a little changed.

The steps up to that of Fig. 1C where the core layer 132 is ridged were conducted to form the core 132a. Then a glass fine particle layer 140 for the upper cladding layer 142 of SiO_2-P_2O_5-B_2O_3 is deposited thereon (Fig. 1D). Conditions for this deposition were a 6 l/min O_2 gas flow rate, a 2 l/min H_2 gas flow rate and a 2 l/min Ar gas flow rate. These conditions were the same as those of the first embodiment, but flow 15   rates of the other gases ($SiCl_4$, $POCl_3$, BCl_3) were as shown in Fig. 7. The deposition was conducted without feeding $POCl_3$ gas, and after some time (about 50 secs.) $POCl_3$ gas was fed at a flow rate of 5 cc/min to deposit the glass fine particle layer 140. This is a main difference of this embodiment from the first embodiment. That is, a glass fine particle layer containing no phosphorus, and a glass fine particle layer containing phosphorus are alternately laid. Thus, the optical waveguide prepared by the fabrication 20   method according to the second embodiment could have a phosphorus doped lower cladding layer 122 and the upper cladding layer 142 which have uniform phosphorus concentrations having a minimum phosphorus concentration indicated by 75 when a maximum phosphorus concentration is indicated by 100. The minimum value in this embodiment was above 95.

Then the glass fine particle layer 140 deposited on the substrate was heat treated by a heating furnace 25   to vitrify the glass fine particle layer 140 and synthesize the upper cladding layer 142, and a buried-type optical waveguide was prepared (Fig. 1E). In this heat treatment, the room temperature (24°C) was raised at a temperature increasing rate of 20 °C/min up to 1300 °C for the heat treatment and retained for 6 hours at the heat treatment temperature, and then lowered to the room temperature at a temperature decreasing rate of 1 °C/min. Thus the glass fine particle layer 140 was vitrified to form the cladding layer 142. A glass 30   film (122, 142) thus synthesized on these conditions had a thickness of 25 μm.

The thus-fabricated buried-type optical waveguide was observed. No foreign objects were generated near the core 132a. Fig. 8 shows a distribution of concentrations of phosphorus pentoxide (P_2O_5) in the section of the buried-type optical waveguide. The C-C' is the analysis line. No deflection of phosphorus near the core 132a was found. A phosphorus concentration in the glass film was substantially uniformly 35   about 0.72 wt%.

To make sure this effect, an experiment for a control was conducted with varied gas flow rates as shown in Fig. 9 for the deposition of the glass fine particle layer 140 (the other conditions were the same). The fabricated buried-type optical waveguide was observed. Foreign objects were found along the side surfaces of the core 132a. A phosphorus distribution was measured along the B-B' analysis line shown in 40   Fig. 10 of this buried-type optical waveguide. A high concentration of phosphorus was detected near the side surfaces of the core 132a (Fig. 10). Many of the foreign objects were found at the location where the high concentration of phosphorus was detected. The generation of the foreign objects is considered to result from contamination of impurities from the inner wall in the reaction vessel 300. That is, to thus form the optical waveguide, very high temperatures are required, and the use of the flame burner 12 is 45   considered to cause convections of the gases in the reaction vessel 300, with the result that impurities mixed in near the core 132a.

As evident from these result, in the method for fabricating the optical waveguide according to this invention, in depositing the glass fine particle layer 140 on the lower cladding layer 122 and the core 132a, the glass fine particle layer 140 is formed higher than the interface between lower cladding layer 122 and 50   core 132a with no addition of phosphorus, and then phosphorus is added, whereby concentrations of phosphorus contained in the vitrified optical waveguide film (the upper cladding layer 142 and the core 132a in this case) can be kept substantially uniform, and generation of foreign objects due to deposition of phosphorus of high concentrations can be suppressed. Thus, the thus fabricated optical waveguide can have smaller propagation losses.

55   In the first and the second embodiments, the raw material gases for forming the glass fine particle layers 120, 130, 140 were, e.g., $POCl_3$ and BCl_3, but instead $POCl_3$, PCl_4, BBr_3, etc. may be fed to the flame burner 12. In the above-described embodiment, a flow rate of $POCl_3$ to be fed to the flame burner 12 was once changed, but it is possible to change a flow rate of the $POCl_3$ in steps or gradually in accordance

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with the progress of the steps.

That is, transient changes of a flow rate of the $POCl_3$ gas are exemplified in Figs. 16A, 16B, 16C, and 16D. In Figs. 16A, 16B, 16C, and 16D time is taken on the horizontal axis, and feeding flow rates (a. u.) of the $POCl_3$ are taken on the vertical axis. A feeding flow rate of the $POCl_3$ is increased from an arbitrary time in step function in Figs. 16A and 16B and linearly in Figs. 16C and 16D up to a set feeding flow rate. Transient increases of a gas flow rate of $POCl_3$ may be increased in two-dimensional function, exponential function or logarithmic function.

When the $POCl_3$ gas is fed, flow rates of the other gases are set constant. It is not necessary that concentrations of phosphorus are uniform throughout the upper cladding layer 142 and the lower cladding layer 122. That is, it suffices that a part of the lower cladding layer 122 near the interface between the core 132a and the lower cladding layer 122 (below a 5 μm thickness from the interface), and parts extended directly above and below the upper cladding layer 142 near the interface of the core 132a and the upper cladding layer 142 (below a 5 μm thickness from the interface). A phosphorus feed amount supplied to the flame burner 12 is increased when parts of the glass fine particle layers corresponding to these parts are formed.

In terms of uniform refractive indexes, it is preferable that a minimum feeding flow rate of the $POCl_3$ is 0 - 40 with a maximum feeding flow rate thereof set at 100. More preferably, its minimum feeding flow rate is 0 - 10. Furthermore, in terms of uniform refractive indexes, it is preferable that a ratio (max/min) of a maximum (max) and a minimum (min) feeding flow rate values of the $POCl_3$ is below 2.5. More preferably a ratio (max/min) between the maximum (max) and the minimum (min) feeding flow rates is below 10.

As described above, in the method for fabricating the optical waveguide according to this invention, in depositing the glass fine particle layer to be the cladding layer 122; 142, a feed amount of phosphorus supplied to the flame burner 12 is transiently increased, and increases of the feed amount of phosphorus to the flame burner 12 are suitably adjusted, whereby concentrations of phosphorus contained in the vitrified optical waveguide film can be substantially uniform. Thus, refractive indexes of the cladding layer can be substantially uniform, and the thus fabricated optical waveguide can have small propagation losses.

Phosphorus is fed to deposit the glass fine particle layer after depositing the glass fine particle layer without feeding phosphorus to the flame burner 12, whereby generation of foreign objects in the interface between the cladding layer and the core can be suppressed.

Thus in this invention, a feed amount of phosphorus is transiently increased especially at the early stage of the step of depositing glass with phosphorus-content flames, whereby phosphorus concentrations in the formed glass film can be substantially uniform. A second method for fabricating optical waveguide which can make concentrations of phosphorus in the glass film uniform includes repetition of the flame hydrolysis deposition step and the vitrification step will be explained by means of a third and a fourth embodiments of this invention.

The third embodiment will be explained with reference to drawings. The same method as in the first embodiment was used to deposit glass fine particles. That is, in the apparatus of Fig. 17, glass fine particles 14 were deposited by mounting Si substrate 110 on a turntable 16 with an internal heater buried in, disposed in a reaction vessel 300, turning the turntable 16 with a surface temperature of Si substrate 110 kept at about 600°C, and reciprocating the flame burner 12 diametrically in the direction of turn thereof. This is known art. Thus the glass fine particles 14 from the flame burner 12 were homogeneously deposited on each Si substrate 110.

A glass fine particle layer 120a for the lower cladding layer of SiO_2-P_2O_5-B_2O_3 was deposited on the Si substrate 110 (Fig. 11A). In depositing the glass fine particle layer, H_2 and O_2 were fed to the flame burner 12 respectively at a 2 l/min flow rate and a 6 l/min flow rate, and raw material gases were fed in the compositions and the flow rates in Table 1, and a depositing time was 15 minutes.

TABLE 1

RAW MATERIAL GAS	FLOW RATE (cc/min)
$SiCl_4$	100
BCl_3	30
$POCl_3$	7.3

The glass fine particle layer 120a deposited on the Si substrate 110 is heat treated with the heating furnace (not shown), and a transparent glass film 122a was prepared (Fig. 11B). In this heat treatment, the

room temperature was raised up to a 1380°C heat treatment temperature at a temperature increasing rate 20°C/min, and the heat treatment temperature was kept for 6 hours and then lowered down to the room temperature at a temperature decreasing rate of 10°C/min.

Then, under the same conditions, a glass fine particle layer 120b was deposited (Fig. 11C) and vitrified to form a glass film 122b (Fig. 11D). Then in the same way, a glass fine particle layer was deposited and vitrified to form a glass film 122c (Fig. 12A). Thus the deposition and vitrification of the glass fine particle layers were repeated three times, and a lower cladding layer 122 of three layers of the glass film was formed. This lower cladding layer 122 had a 30μm-thickness, and each glass film 122a, 122b, 122c had a 10 μm-thickness.

Fig. 13 shows the profile of thickness-wise P_2O_5 concentrations (wt%) in the lower cladding layer 122 on the substrate 110 (Fig. 12A). As shown, a P_2O_5 concentration in the lower cladding layer 122 is substantially 0.5 wt% and in a range of ±0.13. Changes of a refractive index difference Δn is about ±0.002%. Thus it is seen that the P_2O_5 is uniformly distributed, and a homogeneous glass film can be formed. This measurement was conducted by the same EPMA device and the same method as in the above-described embodiments.

Then a glass fine particle layer to be the core of SiO_2-GeO_2-P_2O_5-B_2O_3 was deposited. The conditions for this deposition are the same as described above, but $GeCl_4$ was added to the raw material gases. This glass fine particle layer was heat treated, and a transparent glass film 132 for the core was prepared (Fig. 12B). This glass film was etched in a set pattern by lithography and reactive ion etching (RIE) to form the core 132a (Fig. 12C). As in the lower cladding layer, the formation of the glass film was repeated to form the upper cladding layer 142. BCl_3 was added to the raw material gases for the deposition of the glass fine particle layer, and the heat treatment was conducted at a lower temperature to form a glass film.

Thus, as shown, the lower cladding layer 122 is formed on the Si wafer 110, and the core 132a in the form of linear ridges is formed thereon. The upper cladding layer 142 is formed to cover the core 132a, and an optical waveguide was completed (Fig. 12D). A distribution of P_2O_5 concentrations in these cladding layers are substantially uniform, and the glass films had substantially uniform refractive indexes.

Thus, in the third embodiment the flame hydrolysis deposition step and the vitrification step were repeated three times, whereby glass films having substantially set phosphorus concentration could be formed. But the inventors thought that to reduce propagation losses of the optical waveguide to be fabricated, it is preferable to form a cladding layer having uniform phosphorus concentrations. Then times of repetition of the flame hydrolysis deposition step and the vitrification step were further increased to improve uniformity of phosphorus concentrations. The fourth embodiment which will be explained later is a method for fabricating the optical waveguide in which these steps were repeated six times.

First a glass fine particle layer 120 to be the lower cladding layer is deposited on each Si substrate 110 (Fig. 11A). The conditions for the deposition were the same as in the first embodiment but as shown in Table 2, in the feed amounts of the raw material gases $POCl_3$ feed amount was increased, and a deposition time was 7.5 minutes. The glass fine particle layer 120a was heat treated, and a transparent glass film 122a was prepared (Fig. 11B).

TABLE 2

RAW MATERIAL GAS	FLOW RATE (cc/min)
$SiCl_4$	100
BCl_3	30
$POCl_3$	14.5

The deposition and vitrification of the glass fine particle layer was repeated six times, and a lower cladding layer 122 having six layers of an about 5 μm-thickness glass film was formed in a 30 μm-thickness.

Fig. 14 shows the result of analysis of P_2O_5 concentrations in the thus-prepared lower cladding layer 122. As shown in Fig. 14, in the lower cladding layer 122 a P_2O_5 concentration is substantially 0.5 wt%, and changes of refractive indexes Δn are ±0.0015%. In this case as well, it is found that the P_2O_5 is homogeneously distributed, and a homogeneous glass film could be prepared.

Then, in the same way as in the first embodiment, a transparent glass film 132 for the core was formed (Fig. 12B). Next the formation of the core 132a by etching (Fig. 12C) was followed by the same fabrication steps as in the formation of the lower cladding layer 122, and the upper cladding layer 142 was formed

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(Fig. 12D). A distribution of P_2O_5 concentrations in the cladding layer was substantially uniform, and the thus-fabricated optical waveguide had glass films with substantially uniform refractive indexes.

Fig. 15 shows results of analysis of a P_2O_5 concentration distribution in the cladding layers of controls for making sure the effects of the third and the fourth embodiments (the solid line indicates Control 1, and the one-dot chain line indicates Control 2).

In these Controls, to form cladding layers (film thickness: 30 μm, phosphorus concentration: 0.5%) having the same characteristics as the above-described embodiments, the compositions of the raw material gases of the conditions for forming glass fine particle layers in Table 3 were used (the other conditions were the same as in the above-described embodiments). In Control 1, the glass fine particle layer was deposited with a depositing time set at 22.5 minutes, and the glass fine particle layer was vitrified under the same conditions to form the glass film.

This glass film forming step was repeated twice to form a 30 μm-thickness lower cladding layer having two layers of such glass film. In Control 2, the glass fine particle layer was deposited with a depositing time set at 45 minutes, and then the glass fine particle layer was vitrified under the same condition as the above-described embodiments, and the glass film (lower cladding layer 122) was formed. That is, the formation of the lower cladding layer 122 of a 30 μm-thickness was conducted once as conventionally done.

TABLE 3

RAW MATERIAL GAS	FLOW RATE IN CONTROL 1 (cc/min)	FLOW RATE IN CONTROL 2 (cc/min)
$SiCl_4$	100	100
BCl_3	30	30
$POCl_3$	4.9	2.4

Table 4 compares changes of P_2O_5 concentrations in the lower cladding layers 122, and the deposited glass films.

TABLE 4

	CHANGE IN CONCENTRATION	THE NUMBER OF DEPOSITED LAYERS	THICKNESS OF GLASS FILM FOR ONE LAYER
EMBODIMENT 1	±0.04	3	10
EMBODIMENT 2	±0.04	6	5
CONTROL 1	±0.14	2	15
CONTROL 2	±0.27	1	30

As evident from Figs. 13, 14 and 15, in the phosphorus distribution in the cladding layer, a glass film of a smaller number of deposited layers has larger changes in a phosphorus concentration, the changes of the phosphorus concentrations are not in a range of ±0.13% in Control 1 or 2. It is evident that the changes of phosphorus concentrations indicated in control 1 and 2 are larger at below 10 μm-thicknesswise positions. But such changes are not found in the third embodiment in which one glass film has a 10 μm-thickness. It is found that a glass film formed in a below 10 μm-thickness by one synthesis is free from locally deviated deposition of phosphorus. Accordingly a thickness of the glass film is set at below 10 μm per one layer, and such glass films are laid into a glass layer, such as the cladding layer, whereby glass layers (cladding layers 122, 142) with a substantially homogeneous phosphorus composition can be formed, and changes of a refractive index can be suppressed.

Thus the method for fabricating the optical waveguide according to this invention can form the cladding layers 122, 142 of phosphorus compositions with substantially uniform refractive indexes. resultantly the cladding and the core can have substantially uniform refractive indexes, and the fabricated optical waveguide can have reduced propagation losses.

In the third and the fourth embodiments, raw material gases for the formation of the glass layers 122, 132, 142 were $POCl_3$ and BCl_3. In place of these raw material gases, $POCl_3$, PCl_4, BBr_3, etc. may be supplied to the flame burner 12. In the above-described embodiments, since the core 132a is not as thick

as the cladding layers 122, 142, the core 132a is formed at once, but may be formed by laying glass films as is the cladding layer. The gases may be supplied to the flame burner 12 in the patterns of Figs. 16A, 16B, 16C, and 16D as in the first embodiment.

In the third and the fourth embodiment, the flame hydrolysis deposition step and the vitrification step were repeated plural times to form the lower cladding layer 122. But needless to say, this process is applicable to the formation of the upper cladding layer 142. Thus, according to the method for fabricating the optical waveguide according to the third and the fourth embodiments, the fabricated optical waveguides had the phosphorus-doped lower cladding layer 122 or the upper cladding layer 142 having uniform thicknesswise phosphorus concentrations whose minimum phosphorus value is above at least 75 when a maximum phosphorus concentration is indicated by 100.

As described above, according to this invention, glass films of a below 10 μm-thickness are laid, whereby a core or a cladding layer of a required thickness can be formed. As a result optical waveguide which is free from locally deviated deposition of phosphorus can be fabricated.

Claims

1. A method for fabricating an optical waveguide which comprises
   a lower cladding layer of quartz as a main component formed on a substrate,
   a core of a quartz as a main component formed on the lower cladding layer, and
   an upper cladding layer of a quartz as a main component formed on the lower cladding layer with the core buried in,
   a process for forming the lower cladding layer being a flame hydrolysis deposition step of supplying phosphorus-content gas and silicon-content gas to a burner, blowing glass fine particles of phosphorus-content quartz as a main component from the burner to deposit the same on the substrate and form the lower glass fine particle layer,
   the flame hydrolysis deposition step comprising:
   a step including a period of time in which a flow rate of the phosphorus-content gas is increased with respect to a flow rate of the silicon-content gas, and
   a step of heating and vitrifying the lower glass fine particle layer.

2. A method for fabricating an optical waveguide according to claim 1, wherein the silicon-content gas is SiCl$_4$ in the flame hydrolysis depositing step for forming the lower cladding layer.

3. A method for fabricating an optical waveguide according to claim 1, wherein the phosphorus-content gas is POCl$_3$ in the flame hydrolysis depositing step for forming the lower cladding layer.

4. A method for fabricating an optical waveguide according to claim 1, wherein the flow rate of the phosphorus-content gas is transiently increased step functionally in the flame hydrolysis depositing step for forming the lower cladding layer.

5. A method for fabricating an optical waveguide according to claim 1, wherein the flow rate of the phosphorus-content gas is transiently increased linearly in the flame hydrolysis depositing step for forming the lower cladding.

6. A method for fabricating an optical waveguide according to claim 1, wherein a minimum value of the flow rate of the phosphorus-content gas is 0.

7. A method for fabricating an optical waveguide according to claim 1, wherein a process for forming the core comprises:
   a flame hydrolysis deposition step of supplying the phosphorus-content gas and the silicon-content gas to the burner, blowing glass fine particles of the phosphorus-content quartz as a main component to the lower cladding layer from the burner and form a core glass fine particle layer;
   a vitrifying step of heating and vitrifying the core glass fine particles to form a core layer; and
   a lithography step of etching the core layer by lithography to e expose the lower cladding layer.

8. A method for fabricating an optical waveguide according to claim 7, wherein a process for forming the upper cladding layer comprises:
   a flame hydrolysis deposition step of supplying the phosphorus-content gas and the silicon-content

gas to the burner, blowing glass fine particles of the phosphorus-content quartz as a main component to the core from the burner to deposit the same on the core and form the upper glass fine particle layer; and

the vitrifying step of heating the vitrifying the upper glass fine particle layer.

9. A method for fabricating an optical waveguide according to claim 8, wherein
the flame hydrolysis deposition step for forming the upper cladding layer is a step including a period of time in which a low rate of the phosphorus-content gas is transiently increased with respect to a flow rate of the silicon-content gas.

10. A method for fabricating an optical waveguide according to claim 9, wherein the silicon-content gas is SiCl₄ in the flame hydrolysis deposition step for forming the upper cladding layer.

11. A method for fabricating an optical waveguide according to claim 9, wherein the phosphorus-content gas is POCl₃ in the flame hydrolysis deposition step for forming the upper cladding layer.

12. A method for fabricating an optical waveguide according to claim 1, wherein
the process for forming the lower cladding layer and the core comprises:
a flame hydrolysis deposition step which follows the flame hydrolysis deposition step for forming the lower glass fine particle layer, of supplying the phosphorus-content gas and the silicon-content gas to the burner, blowing the glass fine particles of phosphorus-content quartz as a main component from the burner to deposit the same on the lower glass fine particle layer;
the vitrifying step of heating and vitrifying the lower glass fine particle layer and the core glass fine particle layer to form a core layer; and
a lithography step of etching the core layer by lithography to expose the lower cladding layer.

13. A method for fabricating an optical waveguide according to claim 12, wherein
a process for forming the upper cladding layer comprises
a flame hydrolysis deposition step of supplying the phosphorus-content gas and the silicon-content gas to the burner, and blowing the glass fine particles of the phosphorus-content quartz as a main component to deposit the same on the core and form the upper glass fine particle layer; and
vitrifying step of heating and vitrifying the upper glass fine particle layer.

14. A method for fabricating an optical waveguide according to claim 13, wherein
the flame hydrolysis deposition step for forming the upper cladding layer is a step including a period of time in which a flow rate of the phosphorus-content gas is transiently increased with respect to a flow rate of the silicon-content gas.

15. A method for fabricating an optical waveguide according to claim 14, wherein the silicon-content gas is SiCl₄ in the flame hydrolysis deposition step for forming the upper cladding layer.

16. A method for fabricating an optical waveguide according to claim 14, wherein the phosphorus-content gas is POCl₃ in the flame hydrolysis deposition step for forming the upper cladding layer.

17. A method for fabricating an optical waveguide which comprises
a lower cladding layer of quartz as a main component formed on a substrate,
a core of a quartz as a main component formed on the lower cladding layer, and
an upper cladding layer of a quartz as a main component formed on the lower cladding layer with the core buried in,
the lower cladding layer being formed by repeating plural times
a step of supplying phosphorus-content gas and silicon-content gas to a burner, blowing glass fine particles of phosphorus-content quartz as a main component from the burner to form a glass fine particle layer; and
a step of heating and vitrifying the glass fine particle layer.

18. A method for fabricating an optical waveguide according to claim 17, wherein the cladding layer, vitrified in each of the vitrifying steps has a thickness of below 10 μm.

19. A method for fabricating an optical waveguide according to claim 18, wherein a repetition time of the steps is one of 3 to 6.

20. A method for fabricating an optical waveguide according to claim 17, wherein the silicon-content gas is $SiCl_4$ in the flame hydrolysis deposition step for forming the lower cladding layer.

21. A method for fabricating an optical waveguide according to claim 17, wherein the phosphorus-content gas is $POCl_3$ in the flame hydrolysis deposition step for forming the lower cladding layer.

22. A method for fabricating an optical waveguide according to claim 17, wherein the upper cladding layer is formed by repeating plural times
   a step of supplying phosphorus-content gas and silicon-content gas to a burner, blowing glass fine particles of phosphorus-content quartz as a main component from the burner to form a glass fine particle layer; and
   a step of heating and vitrifying the glass fine particle layer.

23. A method for fabricating an optical waveguide according to claim 22, wherein the cladding layer vitrified in each of the vitrifying steps has a thickness larger than 0 μm and not larger than 10 μm.

24. A method for fabricating an optical waveguide according to claim 22, wherein a repetition time of the steps is one of 3 to 6.

25. A method for fabricating an optical waveguide according to claim 22, wherein the silicon-content gas is $SiCl_4$ in the flame hydrolysis deposition step for forming the upper cladding layer.

26. A method for fabricating an optical waveguide according to claim 22, wherein the phosphorus-content gas is $POCl_3$ in the flame hydrolysis deposition step for forming the upper cladding layer.

27. An optical waveguide comprises:
   a lower cladding layer of quartz as a main component formed on a substrate;
   a core of a quartz as a main component formed on the lower cladding layer; and
   an upper cladding layer of a quartz as a main component formed on the lower cladding layer with the core buried in,
   at least one of the lower cladding layer and the upper cladding layer being doped with phosphorus, and
   thickness-wise phosphorus concentrations in the phosphorus-doped layer having uniformity which is indicated by a minimum value above 75 when a maximum value of the thickness-wise phosphorus concentrations is indicated by 100.

28. An optical waveguide according to claim 27, wherein the minimum value is above 95.

Fig. IA

130
120
110

Fig. IB

a'
a

132
122
110

Fig. IC

132a

122
110

Fig. ID

132a

140
122
110

Fig. IE

A'
132a
A

142
122
110

Fig. 2

LOWER CLADDING

EACH GLASS RAW MATERIAL FEED AMOUNT (cc/min)

SiCl$_4$

SiCl$_3$

POCl$_3$

100

15

3

0

900

2700

GLASS RAW MATERIALS FEEDING TIME (sec)

Fig. 3

CORE

EACH GLASS RAW MATERIAL FEED AMOUNT (cc/min)

SiCl$_4$

BCl$_3$

POCl$_3$

100

15

5

0

900

GLASS PAW MATERIALS FEEDING TIME (sec)
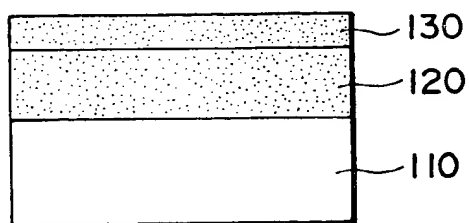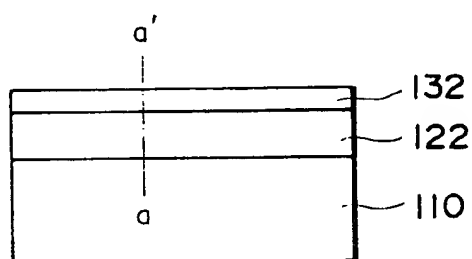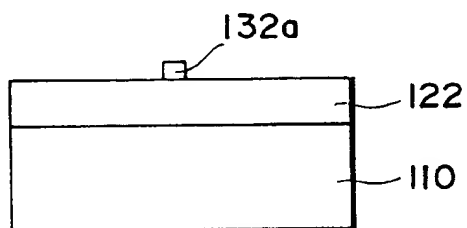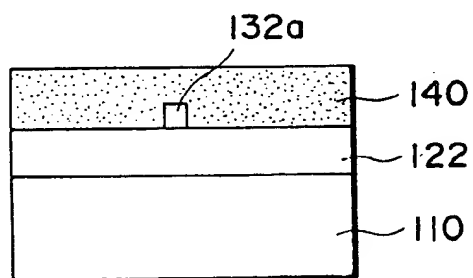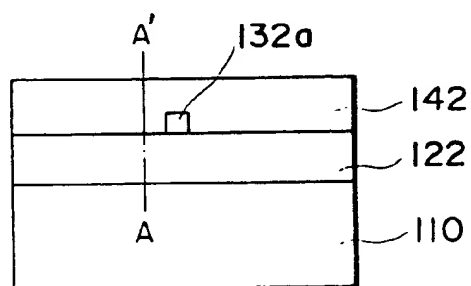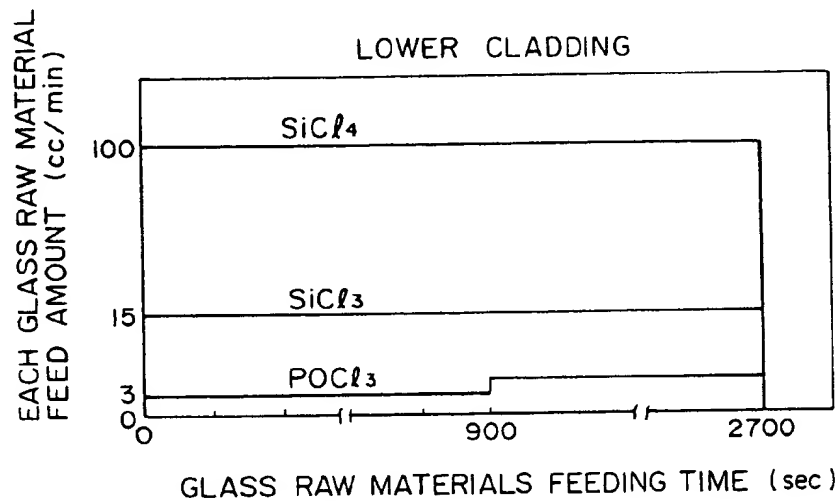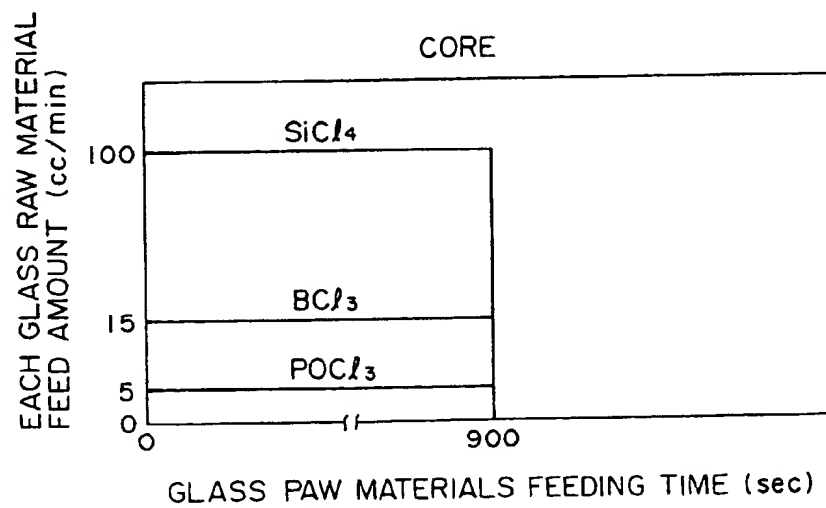
Fig. 4
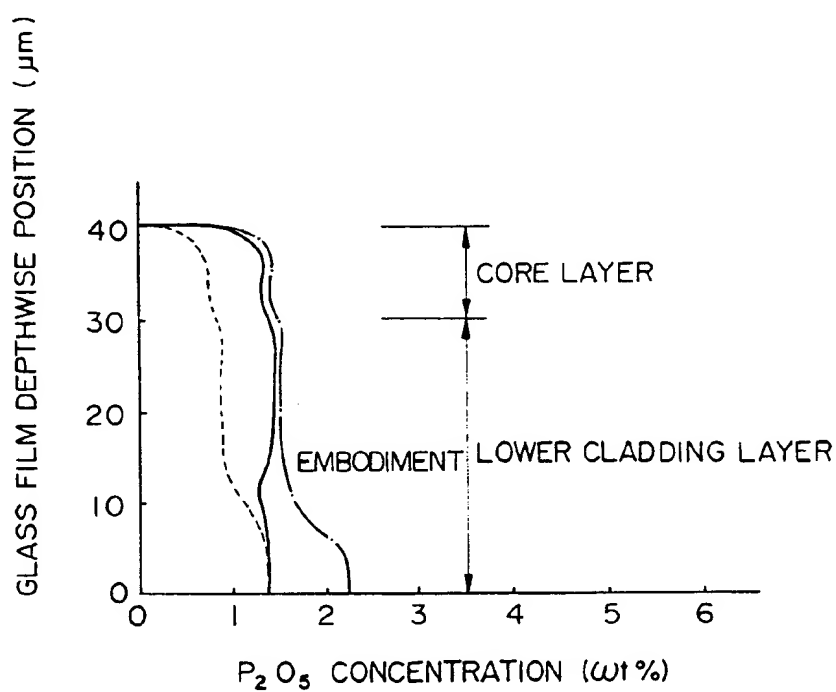
PHOSPHORUS DISTRIBUTION IN GLASS FILM IN
FIRST EMBODIMENT

Fig.5

UPPER CLADDING

EACH GLASS RAW MATERIAL FEED AMOUNT (cc/min)

$SiCl_4$

BCl_3

$POCl_3$

GLASS RAW MATERIALS FEEDING TIME (sec)

Fig. 6

PHOSPHORUS DISTRIBUTION IN GLASS
FILM IN SECOND EMBODIMENT
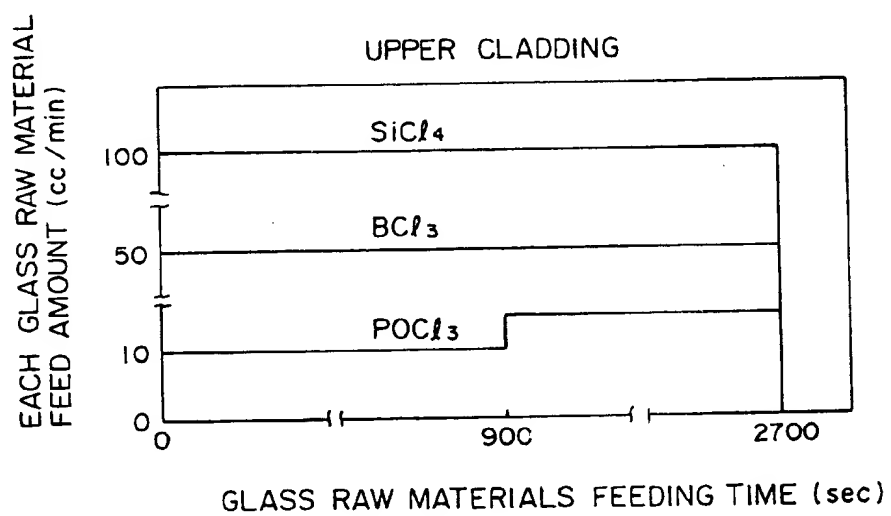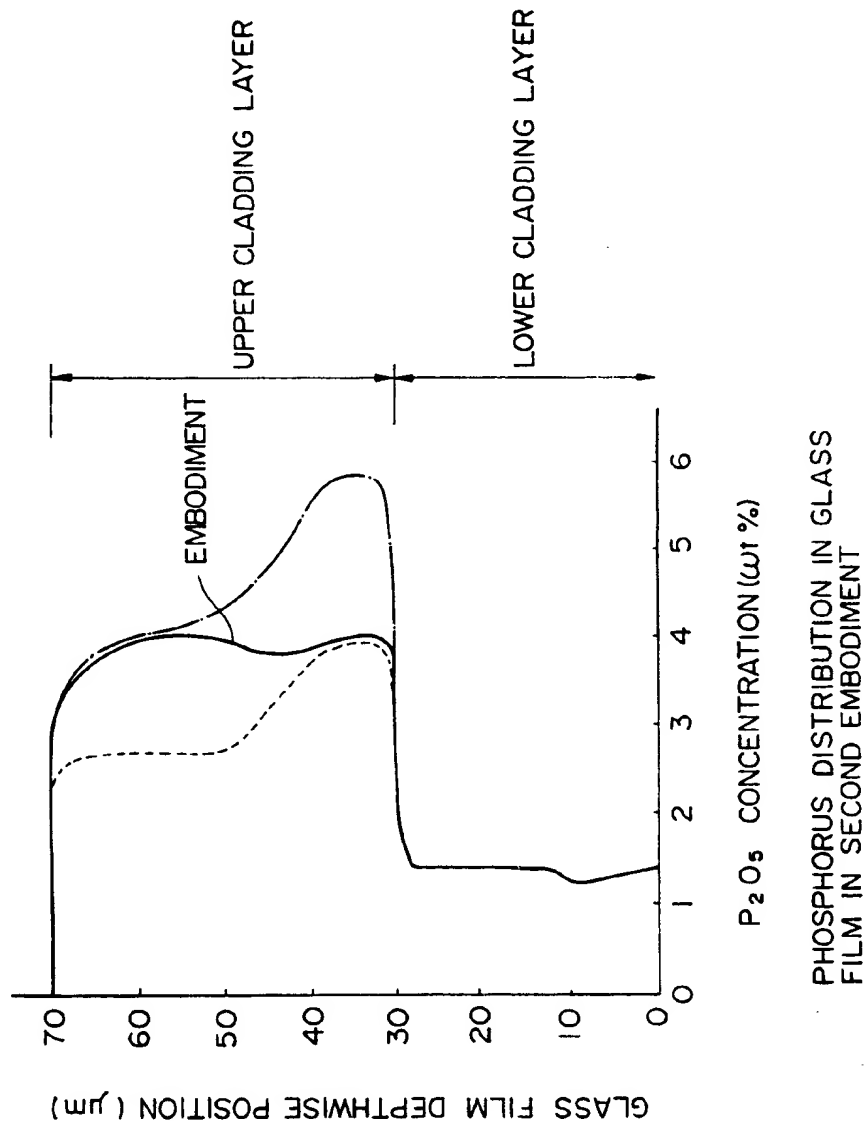
Fig. 7
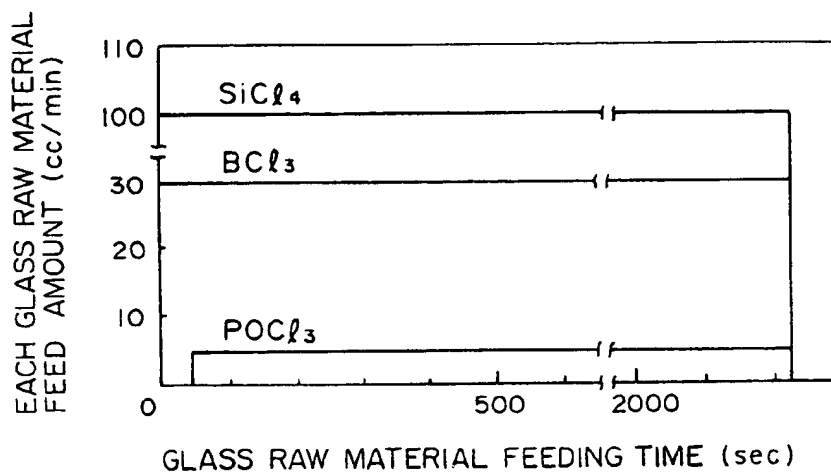
Fig. 8

Fig. 9

Fig. 10

Fig. 11A

120a

110

Fig. 11B

122a

110

Fig. 11C

120b

122a

110

Fig. 11D

122b

122a

110
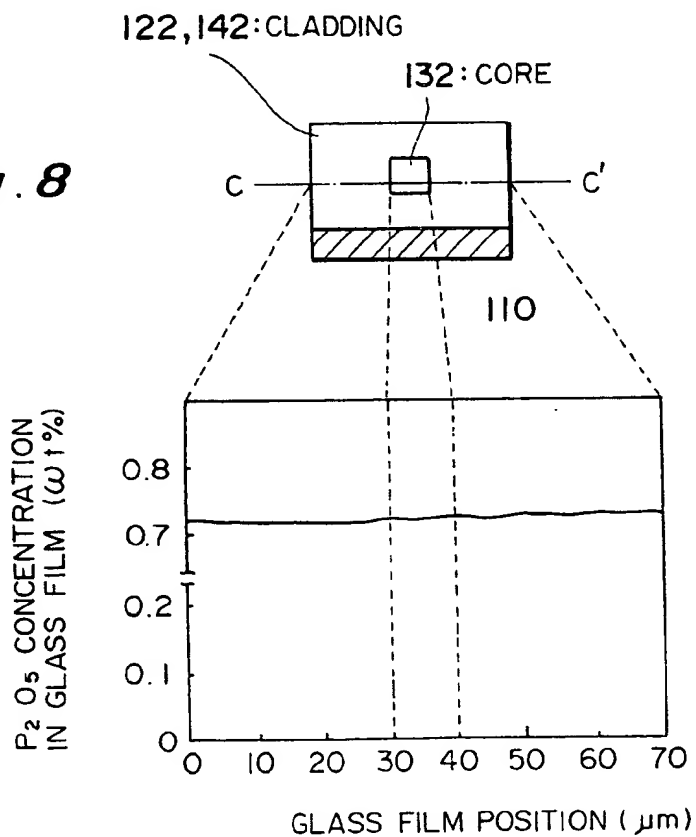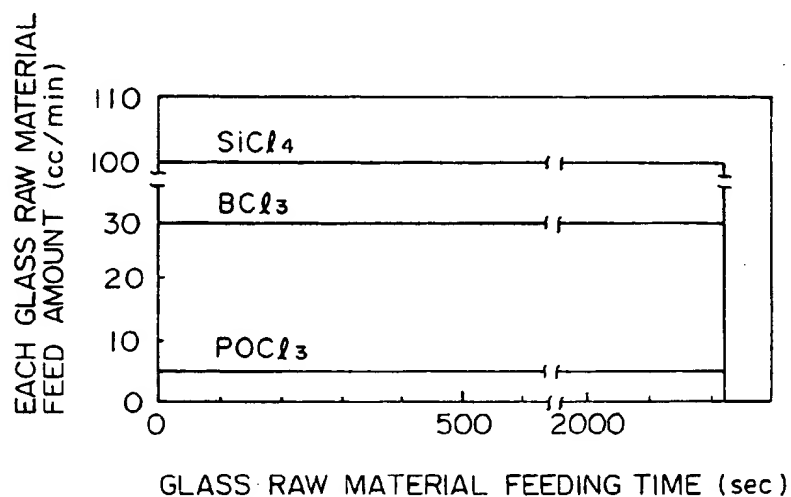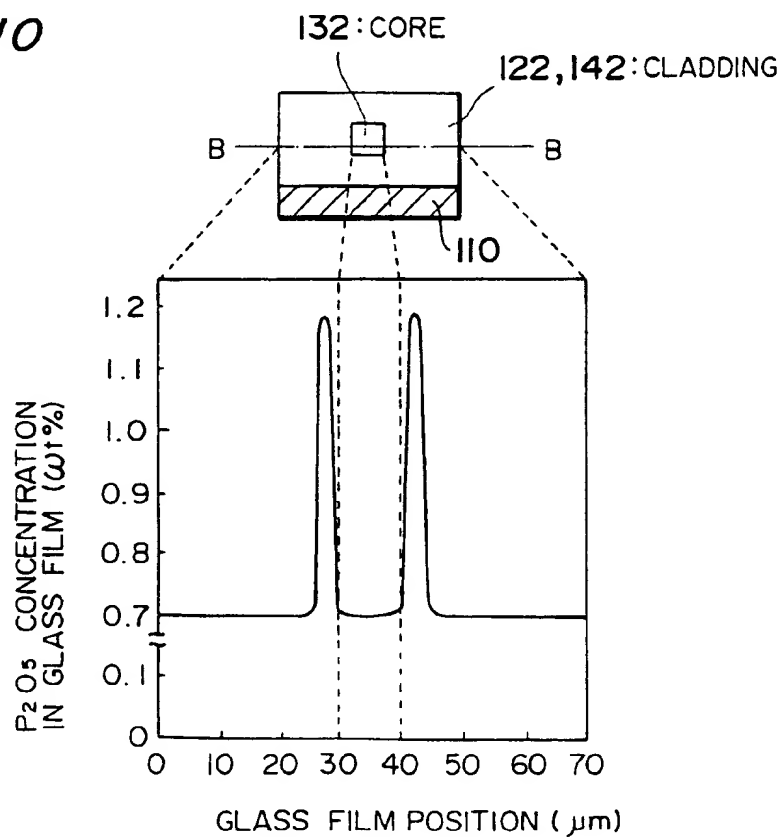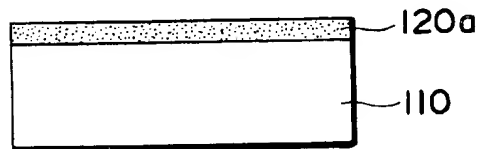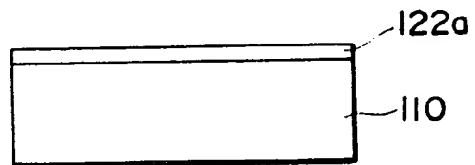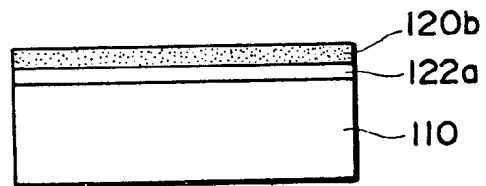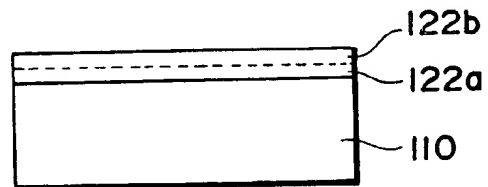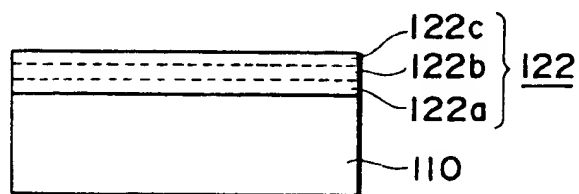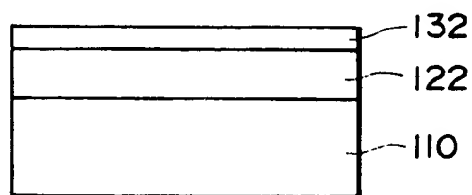
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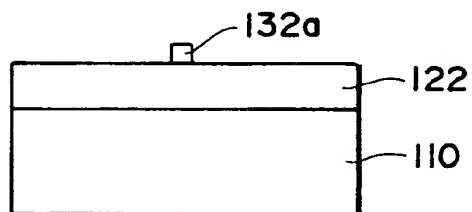
Fig.12B

Fig.12C

Fig.12D
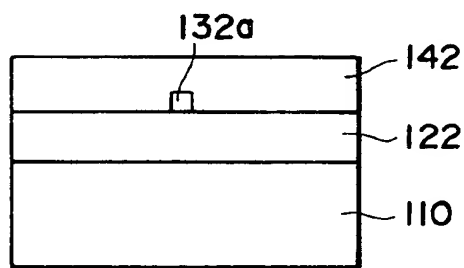
Fig. 13
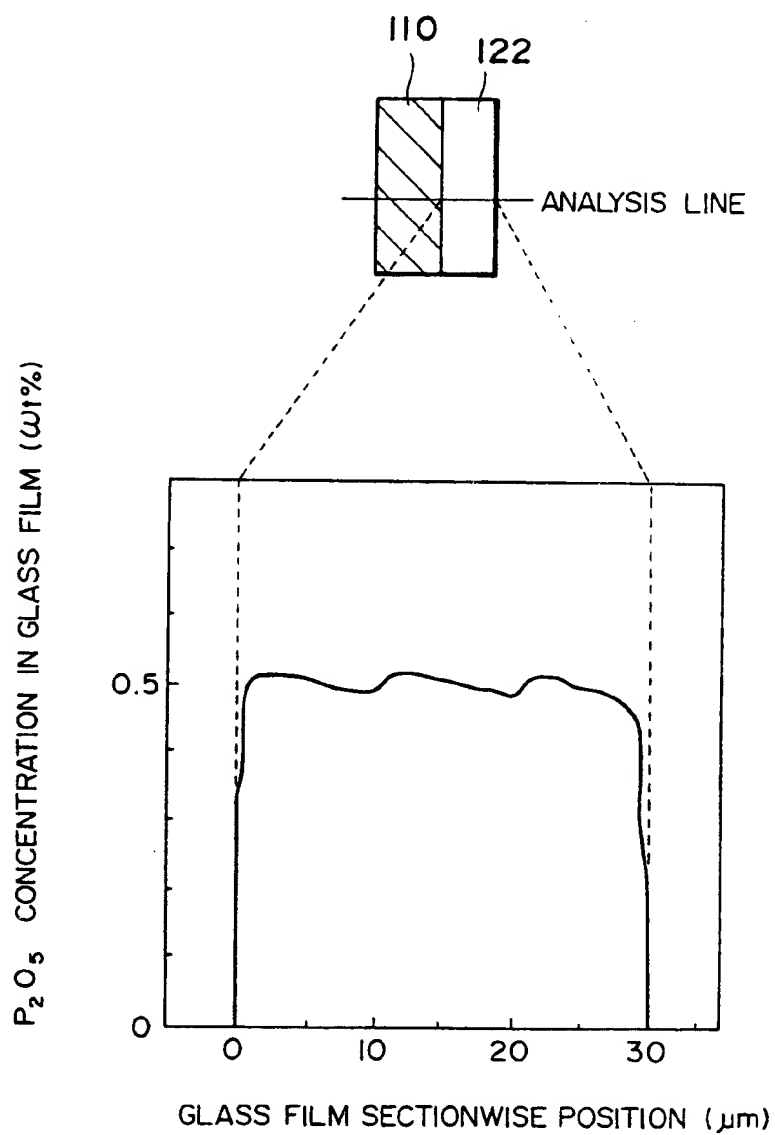
Fig. 14
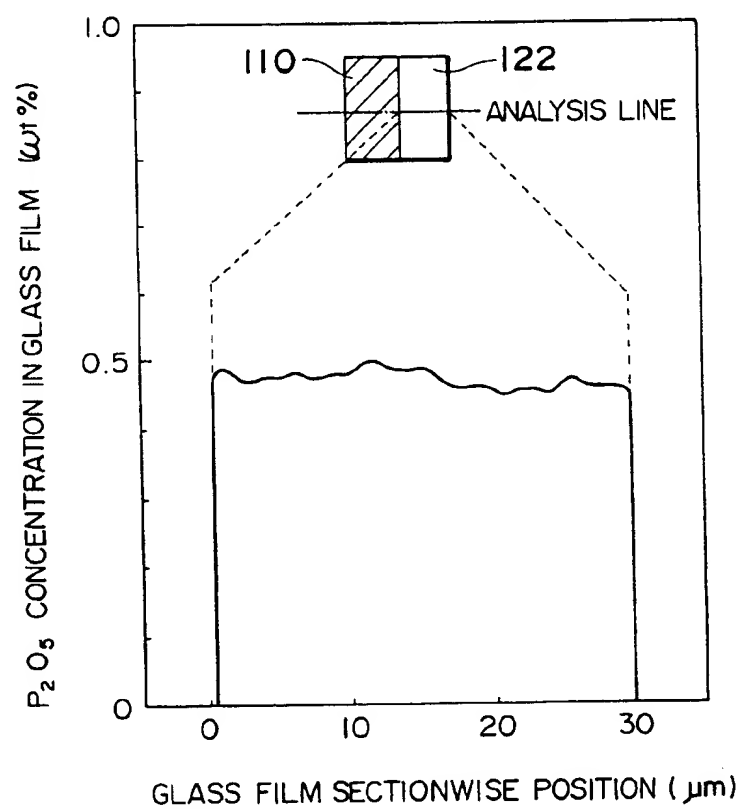
Fig. 15
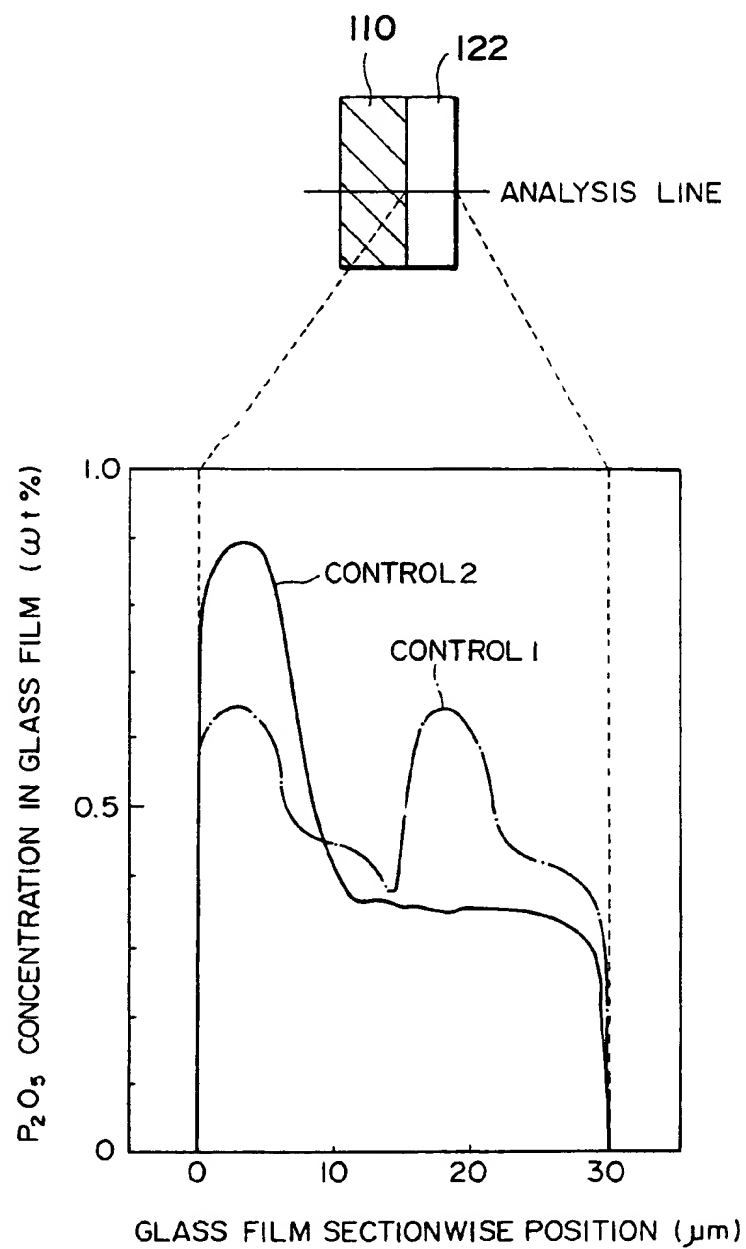
Fig. 16A
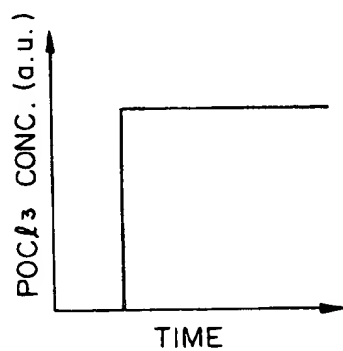
Fig. 16C
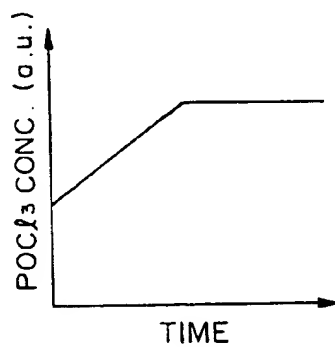
Fig. 16B
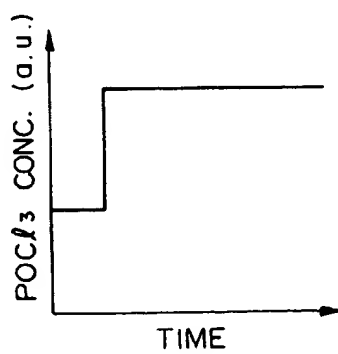
Fig. 16D
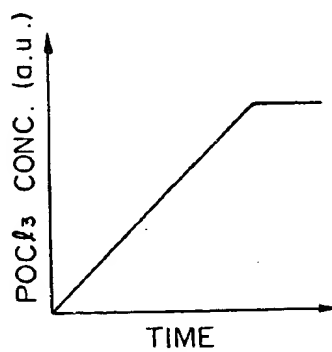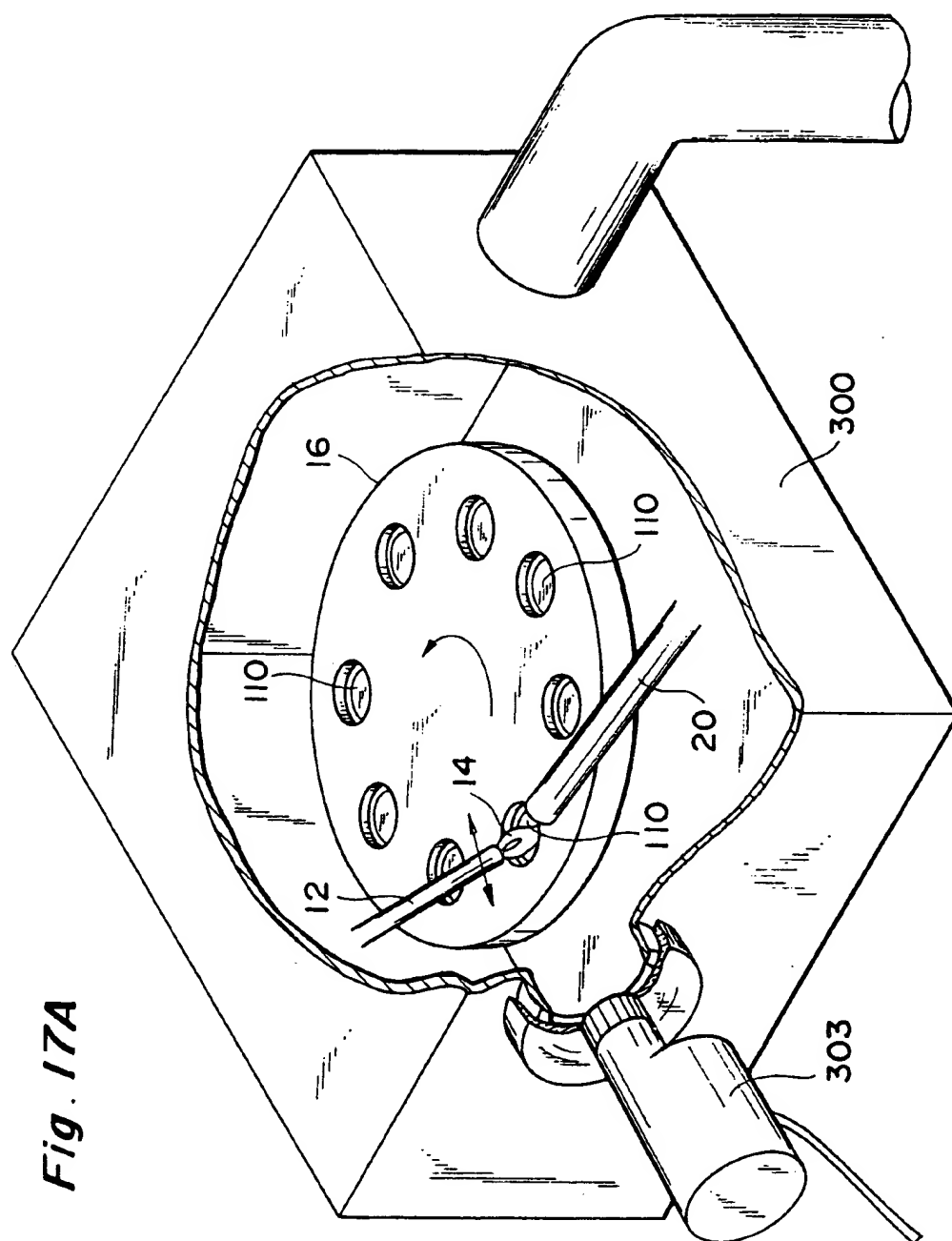
Fig. 17A
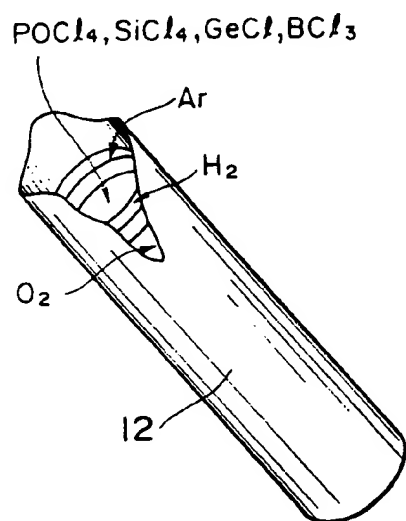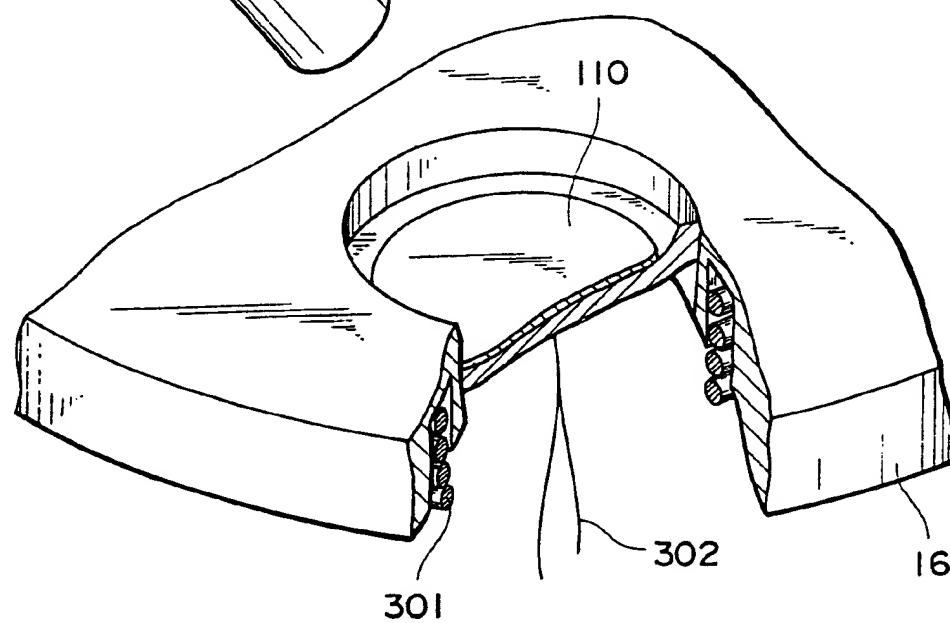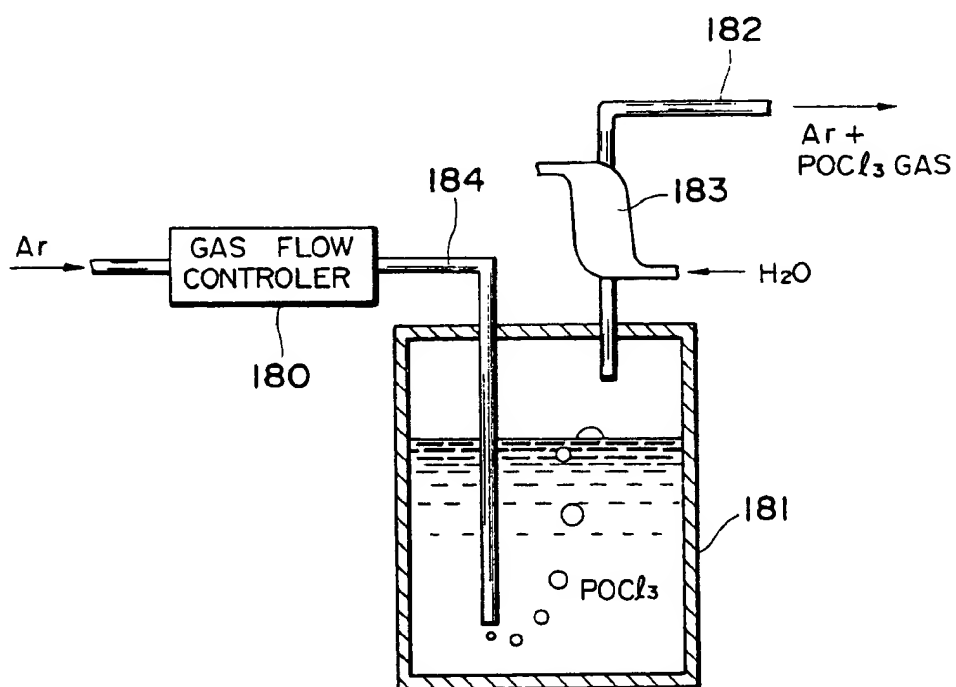
POCl₄,SiCl₄,GeCl,BCl₃

Ar

H₂

O₂

12

Fig.17B

110

301

302

16

Fig. 18

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
Y	GB-A-2 066 805 (NTT) * page 8, line 96 - page 9, line 120; figures 15-18 *	1-8,12, 13,17	G02B6/12
A		9-11, 14-16	

Y	PROC. OF THE ELECTRONIC COMPONENTS & TECHNOLOGY CONF., 20 May 1990, LAS VEGAS,US pages 55 - 59 MIYASHITA 'PLANAR WAVEGUIDE DEVICES ON SILICON' * page 55 *	1-8,12, 13,17	

A	EP-A-0 444 582 (NTT) * page 7, line 16 - line 45 *	1-17	

A	DATABASE WPI Week 8226, Derwent Publications Ltd., London, GB; AN 82-53387E & JP-A-57 081 213 (NTT) 21 May 1982 * abstract *	1-17	TECHNICAL FIELDS SEARCHED (Int.Cl.5) G02B C02C C03B C03C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	27 April 1994	von Moers, F